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THE HYGIENE OF MINES.

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[NOTE.—This paper was presented at the Pittsburgh meeting in a partially completed form, and I fully expected to obtain, before the period of its publication, both the data and the leisure required for its completion. The hygiene of collieries was to have been separately considered, and the sanitary conditions of various metallurgical industries connected with mining were to receive an extended discussion, while at the same time the points treated in the paper as presented at Pittsburgh were to have more ample illustration from American and European sources. Delay in obtaining expected information, and the continuous pressure of professional work, have prevented hitherto the execution of this plan; and I can now publish only a portion of what I had designed to contribute to the subject. In the meantime this portion, but slightly changed, has been included as a chapter on the Hygiene of Metal Mines in a work entitled *Hygiene and Public Health*, edited by Dr. A. H. Buck, of New York. An excellent chapter on the Hygiene of Coal Mines, contributed to the same work by Mr. Henry C. Sheafer, of Pottsville, affords me an opportunity to supply one of the deficiencies above alluded to. Mr. Sheafer's chapter contains much material in the way of explanations not required by professional readers; and he moreover devotes a considerable space to the explosive gases, falls of roof, and other causes of accidents to life or limb—a branch of the subject not belonging strictly to hygiene. I therefore make extracts only from his treatise.—R. W. R.]

IT is convenient to divide mines, with reference to this subject, into two classes, collieries and metal-mines. Subterranean quarries, rock-salt mines, etc., present no conditions requiring them to be separated from the latter class.

With regard to the hygiene of American collieries (a branch of the subject which I shall not discuss at length), I take the liberty of quoting some excellent observations contained in a recent article by Mr. Henry C. Sheafer, of Pottsville. Mr. Sheafer says:

"The working miner usually devotes his whole life to that occupation. He frequently, perhaps generally, begins at the age of from eight to twelve years as a slate-picker in the breaker—the building in which the coal is prepared for market—where his business is to sit all day, with twenty or thirty companions of about his own age, and pick out fragments of slate from a thin stream of coal constantly flowing past him. The place in which he works is apt to be more or less open and exposed to draughts. His clothing consists of shirt and pantaloons, usually old and ragged; a battered cap and a

pair of coarse shoes—the last often omitted in summer. His whole costume, whatever its original color, is soon stained a uniform black by the thick cloud of coal-dust which fills the breaker, filters through his clothing and begrimes his skin, and which forms a large component part of the atmosphere he breathes. As boy and man, his invariable practice at the close of every working day is to wash himself thoroughly from head to foot, a custom to which his hardiness and generally rugged health in early life are to be largely attributed. His diet, as boy and man, is simple. Pork, salt fish, potatoes, and home-made bread are its staple constituents; but when work is good and money sufficient, all the luxuries of the local market are to be found on the miner's table. He learns to smoke and chew tobacco at an early age, has few or no scruples against the use of either malt or alcoholic liquors, and withal grows up to be a lusty, sinewy youth, who seldom troubles the doctors, unless overtaken by one of the numerous accidents to which his own recklessness not less than his somewhat dangerous occupation exposes him. At the age of eighteen or twenty, if he has not previously entered the mine as a driver, or for some other description of boys' work, he goes in as a laborer, becoming in effect, though not in name, an apprentice to a practical miner, with duties so nearly the same as those of his boss, that, for the purposes of this article, they may be considered identical.

"The miner gets to his work shortly before seven o'clock in the morning, if on the day shift, or between five and six in the evening, if on the night shift. He is dressed in flannel shirt, woollen or heavy duck pantaloons, heavy shoes or boots, and usually with a coat thrown loosely over his shoulders. On his head he wears a cap, a slouch hat, or a helmet shaped like a fireman's, but of smaller dimensions. Whatever the headgear, his lamp, a small tin one shaped like a miniature coffee-pot, swings by a hook over the visor; unless the place in which he works is fiery, when he carries a safety-lamp in his hand. His dinner-can and canteen of water or cold tea are swung from a strap passing over his shoulders. Thus equipped he rides down the shaft or the slope, and, if he is lucky enough to catch a train of empty mine-wagons going to his working-place, he rides in, a distance, it may be, of two or three miles from the foot of the shaft. If no wagons are at hand, he walks most of the way through water and slush, taking small account of wet feet, or indeed of wet clothing at any time, though the roof over him may drip all day long. It is an exceptional case if he wears a rubber or oil-cloth suit, even in the wettest places.

"Two miners, or two miners and a laborer, form a gang, and their work is an alternation of exhausting physical labor and intervals of rest. They work with drilling-bar, powder, and pick, getting down the coal and breaking it to a size small enough to handle; with drills, preparing and charging a hole for blasting; with shovels, clearing away the coal and getting it into the mine-cars to be sent to the surface; and then, when a particular job is done, or a blast is to be fired, they repair to the nearest place of safety, and in their overheated condition sit down in the cold, damp draught of the ventilating current to cool off as rapidly as possible. Is it any wonder that rheumatism, consumption, and 'miner's asthma,' are the common ailments among them? In walking to and from his work along the mine gangway, the miner tries to step on the sills on which the track is laid, thus avoiding the hollows worn by the mules' feet between the sills; and as these are laid from two and a half to three and a half feet apart, the effort gives him a long, slow, swinging gait, the head being thrown forward to counterbalance the body. The same posture is found best for traversing the manways and other smaller passages, the long stride being advantageous in picking the way over rough and uncertain ground, while the bent head escapes projections of the roof, and permits the light of the lamp in the miner's cap to fall on the ground at his feet. The habit becomes fixed, and the old miner may always be known by his bent shoulders and swinging stride. That this unnatural compression of the chest cannot but be injurious is evident.

"Among the most laborious of the miner's duties is setting the timbers which support the roof. The gangway, or general passageway of the mine, is usually from seven to ten feet in height, and about the same in width, seldom falling below these dimensions in American mines, where thick beds of coal are worked and the cars are drawn by mule or locomotive power, though in the thin beds of England and Wales, they are often so small that a man cannot stand upright in them. The gangway timbers, unless the rock and coal are unusually solid, consist of a prop on each side, with a cross-piece uniting them. They are from 10 to 15 inches thick, of length adapted to the dimensions of the gangway, and being of green wood, are correspondingly heavy, weighing from 300 to 500 pounds, according to size. Yet three men are not only expected to set the side-pieces, but to lift the heavy cross-beam into position far above their heads, and fix it there. The work is so hard, performed as it is beyond the brattice which supplies fresh air, in an atmosphere more or less

charged with powder-smoke and carbonic acid gas, that, by the time it is done, all three are thoroughly exhausted and overheated, and in most favorable condition for the reception of colds, lung disorders, and rheumatism. If working in a steeply pitching breast,* though the timbers used are not so large, they are quite large enough to tax the strength of the two men who have to get them up a steep and difficult 'manway' by sheer lifting and pulling. In this way, which is almost like working up through a chimney, timbers averaging perhaps eight feet long by six inches thick are carried to the top of the breast, which may be from sixty to eighty yards above the gangway level.

"Mention has been made of the brattice. This is a highly important aid to the ventilation of the mine. It is an air-tight partition, generally carried along one side of the gangway, though sometimes over its top, and so arranged with reference to the ventilating current, that the fresh air is carried along one side of it, while the impure air, which is to be withdrawn, passes along the other. Its object is to keep up a circulation of air in the recess formed by advancing operations at the face of the workings. As every passage or chamber is pushed forward into the solid coal or rock, it necessarily forms a bay, in which the air is always stagnant, unless moved by some such appliance as the brattice. Communicating passages, called headings, are made between the working-chambers about thirty yards apart, for the same purpose; but as the chamber is opened beyond the heading, a brattice becomes necessary here also. One great cause of impurity in the atmosphere in which the miner works is that the brattice is frequently neglected, and the work pushed so far beyond it that it ceases almost entirely to affect the air at the face, which then becomes loaded with powder-smoke and carbonic acid, or, in fiery mines, carburetted hydrogen. In either case the effect on the miner's health is most injurious.

"Of course the principal occupation of the coal-miner is cutting and getting out coal, and here again his work is performed under disadvantageous circumstances as regards the preservation of health. Much of it consists in lying on the side, holing under the mass in a low cut, where every stroke of the pick dislodges a fresh shower

* In steeply pitching breasts of great thickness—say, like the Mammoth Vein in Pennsylvania—timbers are not used, but the miner works the coal on benches, and works from the top rock downward, having his breast constantly full of coal, on which he stands. In coal-beds of ordinary thickness, say ten feet and less, these timbers are used.

of dust, to be inhaled by the miner. Other portions consist of straining at arm's length to dislodge a mass hanging from the roof, of lifting and tugging at heavy weights, of shovelling continuously, hour after hour (where coal has to be shovelled into the mine-cars, the filling of from eight to ten cars, holding three tons each, is considered a day's work for a laborer), and of swinging a heavy sledge in drilling by hand-power. His footing is frequently unsteady, having to be maintained on a steep-pitching floor of smooth slate, so that, as a miner once expressed it to a friend of the writer, 'it is very much like asking a man to stand on the roof of a house while working.' There are chasms under foot and loose rocks overhead, equally to be avoided, and the whole shrouded in a darkness which the miner's lamp reduces only to a semi-obscurity, and which hides without removing the danger.

"The miner's life when not at work also has its effect on his general health, and, as with every other class of men, this varies according to the tastes and temperament of the individual. His house is of frame, plainly but conveniently built, and furnished with the necessary conveniences of life. Being situated in the country, and in a section where land is of little value for either building or agricultural purposes, there is plenty of space about the house, and fresh air in abundance. Even the close neighborhood of frequent hog-pens and occasional stables, and the universal practice of emptying slops from the house on the ground at the back door, have little or no deleterious effect, being neutralized by the abundance of pure air with which their odors and gases mingle.

"The miner's first care on coming from work is to take a tub-bath, cleansing his skin thoroughly. He then dresses in a clean suit, eats his supper, and is ready for the duties and amusements of the evening, both of which are few and simple. Usually the male inhabitants of the 'patch' gather in groups in the open air, in the village store, or in the omnipresent saloon, and smoke and talk, until the coming of an early bedtime sends them home. Comparatively little drinking is indulged in except on pay day, which comes once a month, and is celebrated by the drinking classes with a 'spree.' In this particular the miner's nationality makes itself seen. While men of all nations may be found drinking to intoxication, the practice as a race is confined to the Irish. There are few of American descent among the miners, and these are generally found among the best and steadiest of their class. The Irish are the most numerous, and they are fond of liquor, drink to excess, and are very quarrel-

some when drunk. Terrible fights often accompany a pay-day spree among them. Next to the Irish, in numbers, are the Welsh, a temperate, thrifty, and intelligent race, who form a valuable element in the population. They are industrious and economical, generally succeed in securing homes of their own, which they delight in beautifying and keeping in order, and are apt to be found in positions of trust and authority in later life. Germans and Poles, too, are industrious and economical, but less intelligent and less temperate than the Welsh, more careless in their personal habits, and utterly regardless of the laws of health. They eat unwholesome food, sleep in ill-ventilated rooms, and early acquire a sallow, unhealthy appearance. Nevertheless, their active occupation and the enforced cleanliness of the 'shifting-suit' counteract many of the ill effects of their mode of living, and they will probably be found to average as long lives as the other races. Less numerous, though making up the bulk of the population in certain localities, are Scotch, English, and Italian miners. The last are much like the Irish in habits, while the others hold an intermediate place between them and the Welsh. It is of course to be understood that these remarks apply in general to the nationalities; there are very good workmen and excellent citizens in all classes, and, similarly, there are worthless characters in all; but the general tendency will be found as has been stated. As in every other occupation, personal habits have their effect on the constitution, and predispose it to invite or to repel disease. Thus, drunkenness causes gray tuberculosis, which, with the inhalation of dust and noxious gases, predisposes to consumption, a very common disease in mining towns.

"One of the most prominent conditions of a miner's working life —certainly the first to be noticed by the casual visitor—is the absence of sunlight, a very deleterious condition as many physicians and engineers of large practical experience consider it, while others as positively deny that it has any injurious effect. Dr. J. T. Carpenter, of Pottsville, in a paper read before the Schuylkill County Medical Society, says (*Transactions Medical Society of Pennsylvania*, 1868–9, p. 488): 'The deprivation of sunlight must be a very strongly predisposing cause of disease. It is to be expected that the results of this deprivation will become apparent in general anæmia, in chronic nervous irritations, in tendencies (easily to be developed by exciting causes) toward scrofula, tubercular phthisis, and allied maladies.' Other practitioners, however, assert that the deprivation of sunlight is among the least of the miner's afflictions;

that no injurious effects from it are perceptible, and that no acute disease can be traced either wholly or in part to this cause; while physicians will probably continue to differ forever as to whether or not absence from sunlight during all the working hours predisposes to or prolongs any chronic complaint. In this connection it must be borne in mind that the miner's work is carried on wholly by artificial light, and that usually of a very poor quality. Not the faintest ray of sunlight can penetrate to him, and about the first thing the unaccustomed visitor usually remarks is that it is so *very* dark. It needs but a slight exercise of the imagination to persuade him that he has at last found a sample of that 'thick darkness that might be felt' which once visited the land of Egypt.

"In the winter season, especially when the mines are working full time, their inmates, as a rule, see but little of the sun during their working days. They enter the mine before sunrise, and quit it after sunset. It is, however, a very common practice among them to work week about, one week by day and the next week by night. In this case they have at least from four to six hours of every day's daylight during their night week, and in any case they usually spend Sunday above ground. They do not complain of want of sunshine, and it is difficult to trace any ill effects of its absence upon them. Their complexions are pale, but not more so than those of persons who work at night, or in shaded rooms above ground; and their eyesight, as a general thing, considering the miserable light they have to work by, is remarkably good. Few miners are compelled to wear eye-glasses, for either working or reading, before reaching old age. . . . .

"Too much care cannot be exercised to guard against carbonic acid gas in mines. It not only exists in large quantities in a natural state, but is constantly being formed by the exhalations from the lungs of men and animals, the products of combustion in the miners' lamps, the ventilating furnaces, and especially the small locomotive engines now so commonly employed. When mixed with common air it is only safe up to the proportion of five per cent., though it is said that some miners become so accustomed to it that they can breathe an atmosphere charged with twenty per cent. of carbonic acid. Mr. Andrew Roy, State Mine Inspector of Ohio (Third Annual Report, 1876), calls special attention to the insidious workings of this unseen but deadly foe of the miner. 'The air,' he says, in speaking of the comparatively shallow mines of Ohio, where natural ventilation is depended on to a very great degree, 'is best in the

morning, because the circulation is partially, if not wholly, renewed in the night, during the absence of the miners; but in the afternoon and toward quitting-time it becomes very foul, and miners frequently leave work because their lights will no longer burn, or because they are so oppressed with languor and headache that they can no longer stay in the mine. The black-damp, however, is more insidious than direct in its operations, gradually undermining the constitution and killing the men by inches. By reason of constant habit, young and robust miners are able to stay several hours in a mine after a light goes out for want of fresh air, where a stranger, unused to such scenes, would fall insensible, and, if not speedily removed, would die.'

"Similarly, Mr. J. K. Blackwell, appointed British Commissioner of Mines in 1849, with instructions to make an inspection of their sanitary condition, reports: 'There is another class of injuries, resulting from defective ventilation, to which miners are exposed. The circumstances producing these injuries are slow in operation, and as their effects bring disease, and not immediate and sudden death, their existence has been little considered. These effects are the result of an inadequate supply of air, which has become vitiated and unfit for breathing, on account of its having lost its due proportion of oxygen, which is replaced by the formation of carbonic acid. This gas has its sources in respiration, the lights of the mine, the decomposition of small coal in the goaves (cavities of the roof), and of timber in the workings. Air in this state is also usually found to be loaded with carburetted hydrogen, yielded from the whole coal or in the goaves. Sulphuretted hydrogen, arising from the decomposition of pyrites, is sometimes present, especially in coal-seams liable to spontaneous ignition. The gases formed by blasting are also allowed to load the air of mines to a very injurious degree.'

"And Thomas E. Foster, Government Inspector in 1864, says: 'In collieries that I alluded to as being badly ventilated, they had no inflammable gas, *and that was the reason why they were not well ventilated.* Although you sometimes kill a few men by an explosion, these collieries where they have no inflammable gas kill the men by inches. There are quite as many, in my opinion, killed where there is nothing but carbonic acid gas, as where there is inflammable gas. The men's health is naturally destroyed, and they kill them by inches. They do not go immediately, but they go in for a few years and die.' Attention is especially called to Mr. Foster's remarks. Colliery managers are altogether too prone to

think that fire-damp is the only 'damp' that is to be feared, and force their men to work year after year in an atmosphere loaded with carbonic acid, because in this gas they die slowly and one by one, dropping off without any of the dramatic circumstances attending death by an explosion. It is cause for congratulation that the improved state of science and the requirements of the mining laws in all civilized countries have greatly improved the condition of the mines with regard to ventilation. . . . . .

"Another evil too commonly met with in coal-mines is the cloud of dust with which the air is loaded. Where the coal is kept damp by the percolation of water, little dust is made, and the miner is comparatively free from its injurious effect; but it is exceptional for the coal to be in this condition, and it has been found that the deeper the workings penetrate the less water is found and the drier and more dusty the coal becomes. Any one who has seen a load of coal shot from a cart, or has watched the thick clouds of dust which sometimes envelop the huge coal-breakers of the anthracite region so completely as almost to hide them from sight, can form an idea of the injurious effect upon the health of constant working in such an atmosphere. The wonder is not that men die of clogged-up lungs, but that they manage so long to exist in an atmosphere which seems to contain at least fifty per cent. of solid matter. Ventilation mitigates this evil, but does not obviate it, as a stream of pure water flowing into a muddy pool, of which the bottom is continually being stirred up, will thin the contents of the pool, but will not make them clear. Every fresh stroke of the pick or the hammer, every shovelful of coal moved, every fall of a disloged mass, causes a fresh cloud of dust, until the ventilating current would need to flow with a force little short of a hurricane to keep the miner's lungs supplied with unvitiated air. Inspector Roy, who has given much attention to the subject of mine ventilation, says (Report for 1876, p. 92): 'Constant labor in a badly aired mine breaks down the constitution and clouds the intellect. The lungs become clogged up from inhaling coal-dust and from breathing noxious air; the body and limbs become stiff and sore, and the mind loses the power of vigorous thought. After six years' labor in a badly ventilated mine—that is, a mine where a man with a good constitution may from habit be able to work every day for several years—the lungs begin to change to a bluish color. After twelve years they are black, and after twenty years they are densely black, not a vestige of natural color remaining, and are little better than carbon itself. The miner dies at thirty-

five years of coal-miners' consumption.' Mr. Roy attributes the frequent strikes and other expressions of discontent among the miners primarily to defective ventilation, saying: 'The sources of discontent among miners arise, not, in my judgment, so much in the evil nature of the men, as in the evil genius of the mines; and no conspiracy laws are needed to compel miners to be law-abiding citizens, but better ventilation to expel the demons of the mines—those noxious gases which in remoter ages the priests of Germany were wont to combat with religious exorcisms.' The following cases reported by Dr. William Thomson, show the condition of the lungs above referred to: 'D. C., aged 58; miner for 12 years; lungs uniformly black and of a carbonaceous color. D. D., aged 62; miner from boyhood; lungs uniformly black. G. H., aged 45 years; lungs uniformly deep black through their whole substance, with a density equal to caoutchouc. L. A., aged 54 years; miner all his life; whole lungs dyed with black carbonaceous matter.'

"Dr. R. C. Rathburn, of Middleport, Ohio, testified before the Ohio Mining Commission, on this subject, as follows: 'I have made two post-mortem examinations in which there was carbonaceous solidification in the air-cells. The Scotch people call it spurious melanosis, really a coal-miners' consumption. I have no doubt the carbonaceous particles caused their death. I examined them after death, because before their decease they spit up a black substance whose real character I wished to ascertain. Four cases came to my knowledge.'

"The black substance referred to is solid carbonaceous matter, inhaled while at work. As noted above, it is very slow to operate as a direct cause of death; but aggravates diseases of the lungs, acting principally as an irritant. Once in the lungs it remains there ever after, manifesting itself in a peculiar black sputum in all cases of expectoration from lung troubles.

"Dr. J. T. Carpenter, of Pottsville, in his treatise before quoted, says: 'I saw, a short time since, a patient suffering from chronic bronchitis, with coal-dust sputa, who had not entered a mine for nineteen years. A gentleman of Pottsville, under my care, is now recovering from pneumonia, with softening and abscess of the lung, who in former years was engaged in mines, but has not habitually entered them for eight years past. During his recent illness the characteristic black sputum was constant.'. . . . . .

"After what has been said, it is evident that the greatest necessity for healthful mining is good ventilation. With air-currents

sufficient to carry off noxious gases, powder-smoke, and at least the most of the dust, mining becomes not merely a healthful but an agreeable occupation, notwithstanding all that has been said about its perils and drawbacks. The latter may seem a bold statement to those whose experience in mines is limited to a single visit, but it is the testimony of the great majority of miners, and is confirmed by the well-known fact that men who go from farms and shops to work for a season in the mines rarely go back to the old work. There is something about the comparatively free and easy life of the miner, who is to a great extent his own boss—the uniform temperature, which in most mines varies little, if any, with the seasons, and which ranges from 45° to 65° Fahr., according to local circumstances, the year round—and perhaps the spice of danger which is always present, that makes the miner, once initiated, cling to that work for the rest of his life. Nor is that life necessarily a short one, though the appalling frequency of easily avoidable accidents reduces its average length far below what it should be. So far as the writer is aware, no comparative statistics of the average length of miners' lives, or of their liability to disease, have ever been published; but old men are common among them, and men who have worked thirty, forty, or fifty years in the mines, and are still hale and hearty for their age, are by no means rare. Their principal diseases, as before stated, are miner's asthma, consumption, and rheumatism, and, among those who have worked long in badly ventilated places, dyspepsia, tremors, vertigo, and other troubles arising from blood-poisoning. The two principal causes are dampness and bad air. Pumps and precaution obviate the one, and proper ventilation the other. . . . . .

"In conclusion, it is the opinion of the writer, formed from long personal acquaintance with the subject, and sustained by the almost unanimous testimony of practicing physicians, mining engineers, colliery owners, and miners themselves, that, were it not for accidental injuries and deaths, the mining class would show as good average health, as fair a percentage of longevity, and as low a death-rate as any other class of manual laborers; that the hygienic conditions of American mines are receiving more attention and consequent improvement year by year, and that, if the average miner could only be taught to exercise caution and common-sense about his work, the list of fatal accidents would be materially shortened, and mining would lose most or all of the terrors which now invest it in the minds of the general public."

Coming now to the second class of mines, I wish to inquire

whether the general conclusions expressed by Mr. Sheafer with regard to collieries are equally applicable to metal-mines.

The chief differences in this country between the sanitary conditions of coal-mines and those of metal-mines are the following:

1. The coal-mines are, as a rule, neither very deep nor very high above the sea-level; whereas a large proportion of the metal-mines are situated at great altitudes (5000 to 13,000 feet above tide). The comparative rarity of the atmosphere, though not perhaps injurious to health *per se*, nevertheless intensifies the changes of temperature to which both the mountain climate and the underground work render the miner liable, and thus promotes certain febrile and rheumatic complaints.

2. Although it cannot be said of American metal-mines, in general, that they are deeper than the coal-mines, yet it must be admitted that they grow deep faster, and that the deepest of them far exceed our coal-mines in this respect. In some cases—notably in that of the Comstock Lode—the increase of heat in depth is a very serious inconvenience and injury to the mining work.

3. With rare exceptions, metal-mines do not generate poisonous or explosive gases in large quantity or in brief periods. Slow decomposition in the rocks of minerals such as pyrites may give rise to sulphurous or sulfhydric gases; carbonic acid may be generated by decaying wood, or by the burning candles, or the exhalations of the workmen; but there is no such imminent danger from these sources as threatens the coal-miner, who may be overwhelmed by a sudden irruption and explosion of "fire damp," or drowned in a flood of "black damp." On the other hand, this immunity from sudden catastrophes due to imperfect ventilation leads, in metal-mines, to a degree of carelessness in this department of mine engineering of which no one would dare to be guilty at a colliery. As a rule, therefore, the air is much worse in metal-mines than in coal-mines. The former are usually left to ventilate themselves, according to aërostatic laws; and when changes of wind or season cause a reversal or stagnation of the ordinary current, the phenomenon is submitted to with a kind of fatalism. Miners say "the air is bad" in this or that level, very much as one would speak in helpless resignation about the weather out of doors. When the heat or foulness of the air at any point actually prevents work, remedies are applied; but so long as it is merely an inconvenience or a slight enhancement of the price per yard of contract work, it is too often neglected, since neglect is not exposed to the death penalty.

4. The greater expense and completely unremunerative character of excavations in rock such as usually incloses metalliferous deposits, leads to the making of much smaller and less regular passages than the gangways of collieries; while separately excavated airways may be said not to exist in metal-mines at all—a brattice or an air-box or a weather-door now and then being the most that is done for the artificial direction of the ventilating current. The smallness of the excavations in metal-mines is therefore another cause of imperfect ventilation. On the other hand, the old workings, particularly if well-packed with "deads," or waste-rock, do not need to be ventilated so much as is often the case in coal-mines, to prevent the accumulation of dangerous gases in them.

5. There is, as a rule, much more climbing in metal-mines. The miners often descend and ascend through great vertical distances by means of ladders and stairs.

6. It is in a few localities only, apart from the coal regions, that a permanent class of miners exist. Moreover, the hygienic conditions of most American metal-mines are not extreme; and, finally, the effects often attributed to underground conditions, in other countries, may be largely due to other causes, and it may be that better diet, less prolonged and exhaustive labor, more comfortable homes, and more rational habits have to some extent rescued the American miner from the evils which have been supposed to inhere in his avocation.

The points thus suggested will now be briefly reviewed, under the heads of physical exertion, air, and temperature.

Physical Exertion.—The wielding of sledge and pick, the pushing of cars, the wheeling of barrows, and the lifting of heavy rocks and timbers are forms of exertion which the miner undergoes in common with laborers of many other classes, and which cannot be deemed, apart from the peculiar conditions surrounding them, specially injurious to health, though they are doubtless more or less competent to cause or to aggravate certain organic diseases. The ascent and descent upon ladders may be considered characteristic of this avocation, though it is involved also in the ordinary method of raising bricks and mortar to buildings in process of construction. Here the hod-carrier not only climbs, but climbs frequently, and carries a heavy load—a practice once common in the mines of Mexico and South America, but unknown in this country, from which its cost as well as its inhumanity has excluded it. It is the custom now to use windlasses or hoisting engines even for buildings, when these exceed

one or two stories in height; and it must be remembered that the highest buildings come far short of the vertical extension of ordinary mines. The question, how much the health and efficiency of miners are affected by climbing up and down ladders, has been carefully examined. The loss of working-time involved in this method of transit is serious. But the exercise of climbing itself, if taken slowly and with due caution, and if the heated climber is not afterward exposed to a chill, is not generally held to be injurious to healthy and strong men. Added to other enfeebling conditions, it is said to hasten the period of declining strength; and it is an important objection to the use of ladders in deep mines that they necessitate the employment of the younger men in the lower levels, and thus deprive the mine, at the points where skilled labor is most desirable, of the services of the oldest and most experienced workmen. Ladders placed at a proper angle are better than stairs, since they permit the arms to take part in raising the body. The loss of time and the waste of strength involved in ladder-climbing are shown by the relative amount of work done per man in the upper and lower levels, this amount being, for instance, in the lead-mines of the north of England, one-fifth greater in the upper levels. On the question of health, it may here be added that sailors are not reported to suffer from climbing any more than bricklayers do; and the sum of the whole discussion appears to be, that the economical view of the subject of climbing in mines is more important than the sanitary one.

This view has led to the introduction of the man-engine, and the practice of lowering and raising workmen in skips and cages. This is not the place for a criticism of the comparative merits of these devices. It is sufficient to say that in most of those American mines which are deep enough to render the use of ladders a matter of hygienic importance, the workmen are lowered and raised by the machinery that hoists the ore; and the ladders being kept merely as a means of transit between neighboring levels, or as a resort in case of accident, do not enter into the hygienic problem.

Air.—The most thorough and satisfactory reports on the air of metal-mines are those of Dr. R. Angus Smith and Dr. A. J. Bernays, included in Appendix B to the Report of the Commissioners, appointed to inquire into the condition of the metal-mines of Great Britain, with reference to the health and safety of the persons employed in such mines. (London, 1864.) Dr. Smith begins with an elaborate discussion of the normal amount of oxygen and carbonic

acid in pure air, and, after citing many analyses of distinguished chemists, adopts 20.9* parts by volume of oxygen, and 0.04 of carbonic acid as a fair outdoor average, and shows that in confined spaces, and under various influences, the amount of carbonic acid may be increased indefinitely. At 11 P.M., in the pit of a London theatre, it was 0.32. But many samples of bad air, taken from mines, have shown over two per cent. of carbonic acid. By a series of most interesting experiments, conducted in a hermetically closed lead chamber, containing 170 cubic feet of air, Dr. Smith established, among other important results, the following:

A person shut up in the chamber for five hours raised the amount of carbonic acid to 2.25 per cent. In this atmosphere the breathing was changed from 16 inspirations per minute to 22, and the pulse fell from 76 to 55, becoming, at the same time, so weak that it was difficult to find. On another occasion, when the carbonic acid had risen to 3.9 per cent., the number of inspirations advanced to 26, and the pulse became so weak as to cause alarm. This is a symptom of poisoning by carbonic acid. An experiment, tried by blowing carbonic acid into fresh air, containing 20.1 oxygen, without removing the oxygen, showed that the pulse of the subject was weakened, though breathing was not very difficult, and the candles burned moderately well. Four miners' candles, inclosed in the chamber, ceased to burn at the end of five hours, having raised the temperature from 50° Fahrenheit to 65°, and vitiated the air until it contained 18.8 oxygen and 2.28 carbonic acid. It follows that men can live where candles will not burn; but that the poisonous effect of carbonic acid begins before its subject is conscious of serious inconvenience. Moreover, it appears that the presence of carbonic acid is a more noxious agency than the mere diminution of oxygen in an otherwise pure air. According to Dr. Smith's experiments, respiration is not affected sensibly by a small or even a considerable diminution of oxygen, when the place of that gas is not taken up by others of a harmful character. But we do not usually have to deal, in mines, with simply rarefied or deoxygenated air. The abstraction of oxygen is due to processes which load the air with such gaseous products as carbonic acid. The facility with which water absorbs certain percentages of its weight of carbonic acid and other gases, explains the fact that the air is more tolerable in wet than in dry workings. Trickling streams or spray perceptibly improve the

* The proportions given throughout this paper are parts in 100, by volume.

ventilation; and this means is occasionally resorted to for enabling men to continue work where it would otherwise be difficult.

Dr. Bernays points out another most important fact, namely, that there is a great difference in the personal sensations of comfort or distress occasioned by breathing different atmospheres containing practically the same proportion of carbonic acid. This is undoubtedly the effect of organic impurities, which greatly aggravates that of the carbonic acid. A much larger proportion of the latter may be breathed with impunity when it is the result of inorganic processes, and particularly of the slow oxidation of coal, than when it proceeds from animal exhalations, and the quick, smoky combustion of candles. Dr. Bernays says that he has often found the air of a crowded room intolerable, though it contained not more than 0.1 per cent. of carbonic acid. He mentions also, as a curious fact, that a man may continue to breathe without distress in a confined space so long as it is contaminated by his own breath only, though he could not, without great disgust, enter an atmosphere rendered equally foul by the respiration of others. But I suspect that the inference he suggests is not well founded. It is, perhaps, not the source of the contamination, but the entrance of the observer from purer air, that makes it more repulsive in the latter case.

Carbonic acid and accumulations of organic impurities are most troublesome at the ends of galleries, or in confined stopes, winzes, etc., which are not swept by the general current of ventilation. The operation of blasting in such places has the good effect of breaking up the stagnation of the air; but, on the other hand, it contributes certain impurities of its own, partly volatile, and partly in fine, suspended floating particles. Carbonic acid, sulphuretted hydrogen, suphide and nitrite of potassium, etc., are among the products of explosion from ordinary gunpowder. Gun-cotton is less harmful in this respect, and was recommended by the British Commission; but it has never found general application in mines, perhaps because its use in mines, as a quick and violent explosive, has been superseded, or rather forestalled, by the various nitroglycerin compounds. It is well known that the gases from these produce most distressing headache; but this appears to be the effect on those persons only who are unaccustomed to them. I have seen miners return to a stope almost immediately after a blast of dynamite, apparently without inconvenience. This was, however, in a well-ventilated mine. With all explosives it is necessary and customary to allow the gases to clear away before resuming work.

Sulphuretted and arsenuretted hydrogen may be given off by rocks which contain such minerals as pyrites of iron or copper, mispickel, etc., which undergo decomposition in the presence of air and moisture. To this cause, in part, may be due the alleged unhealthiness of the copper-mines of Cornwall as compared with the tin-mines, in which the ore, being already an oxide, suffers, upon exposure, no chemical change.

Besides the gaseous impurities of the air, the dust produced by drilling has been considered a source of disease. This is probably not a serious evil. The almost invariable practice is to put water in the bore-holes to facilitate the work, and there is from this source little or no dust to be inhaled. What has sometimes been mistaken for mineral dust in post-mortem examinations of the lungs of miners, is finely divided carbon; and this is almost certainly attributable, not so much to the occasional inhalation of gunpowder vapors as to the constant breathing of the products of the imperfect combustion of candles. Some reported cases of the "lead-colic" among lead-miners may have been due to the inhalation of plumbiferous dust, or to the drinking of poisoned water.

The effect of all these impurities of the air has been found on the continent of Europe and in Great Britain to be a peculiar form of "asthma," "consumption," or "anæmia," known as the miners' disease. It is difficult to say how much the general low tone of vitality due to insufficiency of animal food, lack of healthy dwellings, and reckless personal habits, contributes to the prevalence of this disease; but it is probably fair to conclude that these causes weaken the ability of the workman to resist the effects of the impure air in which he works.

Temperature.—There is a gradual increase of temperature in the rocks of the earth's crust, below the zone of uniform temperature which is found near the surface. The law of this increase in temperature is not clearly established. It is certainly much affected by the chemical reactions which may go on in the rock. Mr. Robert Hunt, in his testimony before the British Commission, says that whatever may be the temperature of the atmosphere on the surface of the earth, there is in the Cornish mines a constant temperature throughout the year at the depth of about 150 feet. Below that point, he says, the increase is one degree Fahrenheit for every 50 feet down to about 750 feet; then one degree in every 75 feet down to about 1350 feet; and below that about one degree to 85 feet. Mr. Henwood (quoted by Prof. J. A. Church, in his paper published in the previous vol-

ume of *Transactions* on the Heat of the Comstock Mines) gives for different kinds of rock the following distances in feet, corresponding with each rise of one degree: granite, 51; slate, 37.2; cross veins, 40.8; lodes, 40.2; tin lodes, 40.8; tin and copper lodes, 39.6; copper lodes, 38.4. These figures show how great is the variation due to local causes. Assuming the increase in granite to be least affected in this way, and applying also Mr. Hunt's formula for the rate of increase, we may adopt as a probable standard of comparison a scale of depths and rock temperatures, as follows:

Depth—Feet.	Temperature of rock.
150, ...	. 60°
300, ...	. 62°
600, ...	. 66°
1350, ...	. 76°
2000, ...	. 84°

It will be generally admitted that most mines are hotter than this, the fact being that the heat given off by lights, explosives, animals, and men is not immediately removed by the ventilation, and hence the rock is perceptibly cooler than the air. But chemical reactions and hot springs in the rock may very greatly raise its temperature; and when this is the case the miners, finding that the rock feels hot, in comparison with the air, say that the lode or the wall "makes heat." Even when the air is still somewhat the warmer, the rock may seem to be so when touched with the hand.

One of the United mines in Wales is mentioned by Prof. Church, in the paper already cited, as possessing springs which discharge water at 116° Fahr., the depth being 1320 feet. The heat of the air in the workings is given at 100° to 113° Fahr. The hottest mine in Cornwall is, or was in 1862, the Wheal Clifford, concerning which the superintendent, John Richards, testified that the temperature was 102° fifty-one feet below the 1200 feet level, and a "pretty deal hotter" (120° he guessed) at the 1380 feet level. At one time, in a confined working, the temperature was known to rise as high as 128°. Mr. Robert Hunt, speaking apparently of the same mine, says that, by his personal measurement, the air showed 110° in the deep level, and that tests of the rock, made by leaving a thermometer for two hours in a bore-hole, gave from 112° to 114°. He reports the maximum with which he was acquainted as 117°. Mr. Richards says the workmen can endure 120° perhaps half an hour, but cannot continue to work for an hour at 102°, while they can make

a four-hour shift without interruption at 95°. Mr. Hunt gives the average time of working at twenty minutes, and says that, on retreating, the men washed themselves in water at 90°, to cool off. Six sets of men were employed, so that each set had one hour and forty minutes to recover from the effects of the twenty minutes' exertion. Four turns of twenty minutes, thus distributed through an eight-hour shift, constituted a day's work. It is not surprising that, under these circumstances, the labor account was heavy. It is said that three guineas per inch was paid for driving a cross-cut in this mine.

These remarkable statements are even surpassed by the recent experience of the deep mines on the Comstock Lode in Nevada. For many data on this subject, corroborating and completing my own hasty observations and recollections, I am indebted to the paper of Professor John A. Church, already mentioned, and to the unpublished memoranda of that gentleman, generously placed at my disposal. In the lower levels of these mines (say about 2000 feet below the croppings of the Gould and Curry, the usual datum-line) the temperature of the rock is generally about 130°. In freshly opened ground the air usually varies from 108° to 116°; but higher temperatures are not unfrequently reported, as, for instance, 123° in the 1900 feet level of the Gould and Curry. The water, which enters the drift from the lode and the country rock, is, however, often much hotter. The vast body which filled the Savage and the Hale and Norcross mines for many months had the temperature of 154°. But the water, like the rock and the air, varies in this respect in different portions of the mines. The ordinary range of "hot drifts" is 105° to 110° air-temperature. The ventilating current is delivered at a temperature of 90° to 95°, which seems to be most conducive to comfort. It is blown upon the men through zinc pipes by means of powerful mechanical blowers. The question of present interest being the effect upon the health of the miners of working under such conditions, further description of the peculiar phenomena of the case will be unnecessary.

Before considering the health of the Comstock miners, it should be noted that by no means all, or even the majority of them, are employed in the hot drifts, and, moreover, that these mines are provided with arrangements which enable every miner to bathe and change his clothing immediately upon emerging from underground.

The diseases of the Comstock miners are mainly typhoid and mountain fever, rheumatism, and erysipelas. There is little or no

consumption, bladder, kidney, or liver disease. The superior ventilation (apart from the question of temperature) in the mines, the hearty and abundant diet of the miners, the constant enormous activity of their perspiratory functions, and the personal cleanliness resulting from their daily baths, seem to have abolished among them the disease, supposed elsewhere to be characteristic of their avocation. It is admitted by all observers that they are healthier than their wives and children.

As to the immediate effect of the high temperature upon those who work in them, it must be confessed that, while actually working, the men display apparently undiminished vigor, delivering with seven, eight, or even nine pound hammers, very rapid and effective blows. Perhaps a third of the time is lost in resting and cooling. In very hot drifts, a relief gang is employed; and, in extreme cases, four and even six men to the pick have been found necessary. In the main, however, the rapid progress in the hot drifts is remarkable, and shows that the heat does not greatly lessen the power of work, except by necessitating longer or more frequent rest. At the usual temperature of 108°, three shifts of three men each, working in turns of eight hours, advance three to five feet daily in hard rock. This is so much better than the efficiency reported from the hot lode in Cornwall, that we are led to infer that the method of delivering air to the Comstock drifts affects the temperature and perspiration of the miners in such a manner as to protect them to a large extent from the otherwise distressing action of the heat. My own sensations, as I recall them, in a deep and very hot level of the Crown Point (about 116°, I believe), were not specially uncomfortable on the surface of the body, except when a drop of still hotter water fell upon me. The principal feeling of distress was internal, and was caused by the inhalation of the scorching air.

The question whether those who labor in such places are permanently injured, is more difficult to decide. One of the physicians at Virginia City has declared that "there is not a sound heart in any man on the lode who has worked in a hot drift for two years." This statement is perhaps too strong, though it is possibly true that many of the miners are organically affected. Yet this appears not to interfere with ordinary and equable work, though it may, perhaps, develop into distinct disease under special strain or excitement. After long work in the hot drifts, the men have a waxen color, and are known as "tallow-faces." Prof. Church noticed some men who, without being lazy, showed unusual care in handling their

work, and two or three of them told him that they were "broken down" in hot drifts. In the only instance in which the time required for "breaking down" was given, the workman had been employed underground six years.

The actual effect of the heat on the men is, first, excessive perspiration, and, if this is not removed by evaporation with sufficient rapidity, great faintness. The pulse increases, as is shown in the following interesting data, obtained by Prof. J. D. Whitney and Prof. Church, in the 1800 feet level of the Julia Mine, the drift being about 1200 feet long, and having an air temperature of 108° to 110°, while the air temperature at the station or junction of the drift with the (downcast) shaft was only 84°. The following observations were made:

	Pulse-beats per minute.
Carman, after bringing out car, say 1200 feet,	140
Carman, after resting at station,	64
Carman (another case), after partial rest,	128
Prof. Whitney, after walking through drift,	120
Prof. Whitney, normal rate,	60
Prof. Church, after moving about, without exertion,	88

A case of death is reported as follows: A powerful man, accustomed to hot drifts, returned to work after a rest of three months, and entering the Imperial Mine as carman, pushed his first car to the end of the drift, in the 2000 feet level—say 1000 to 1200 feet—loaded it, and brought it back to the station, where another man was waiting to relieve him. But, instead of taking his turn, he dumped the car and started back without cooling off. He loaded the car again at the end of the drift, and proceeded to return, but was found a few minutes later hanging senseless to his car, and died, I believe, before he could be got to the surface. Another died in the Imperial incline while that was sinking. Three such deaths in all are reported from this mine, which is an excessively hot one. Sometimes accidental deaths may be the indirect result of the faintness caused by the effect of the heat on the circulation. Thus a man fell down the Imperial (upcast) shaft last year, who was probably overcome by the heat while putting in timbers. In these worst places, strong and healthy young men are employed. Fat men seem to stand the heat best, and, among visitors, women endure it better than men. Some men wilt under the work, and are said to have "no pluck." Drinking habits unfit the miner for this severe test.

Unaccustomed men are often unable at first even to reach the end of the drift where they are to work. An intelligent miner told Prof. Church that the first month of such work after a long rest is hard; then comes three months of brisk feeling; and then follows a "dragged-out" sensation.

The underground use of machine-drills, operated by compressed air, is an important aid to ventilation and cooling, since the expansion of the escaping air absorbs much heat from the immediate neighborhood. But when, as in the Comstock, the heat radiated from the whole surface of exposed rock is far in excess of that which men and lights supply, nothing can sensibly reduce it, or mitigate its effects, except abundant mechanical ventilation. This is carried to a large extent in the Comstock mines; and to the fact that, in counteracting the high temperature, the impurities of the air are thus removed, the remarkable good health of the Comstock miners may be partly ascribed. Other causes have been already mentioned, such as the healthy mountain climate, the good food, and the comfortable dwellings. Finally, the fact must not be omitted from consideration that the miners of our Western regions are emigrants, and presumably men of such bodily vigor and health as their adventurous spirit would imply.

Incidental to the question of temperature is the effect of sudden changes of temperature, such as are experienced on coming suddenly from the depths of a mine to the surface. The hygienic conditions here do not differ from those which any similar change of temperature produces; and since they may easily be counteracted by the prudent miner, they need not be set down as sources of disease inherent in his occupation.

Another kindred question relates to the effect of barometric pressure, which varies in mines with the depth of the openings, and also with the changes of the outside weather. The general experience is that high barometric pressure, though it permits a greater inhalation of oxygen with each breath, causes a feeling of distress, and affects the heart unfavorably. Dr. Bernays says that undoubtedly the most injurious, as well as the most unpleasant, condition of mine air is that in which a high temperature is accompanied with excessive barometric pressure and great humidity. The effect of the pressure alone can best be studied in the records of work in highly compressed air, as in the sinking of the caissons for the East River and other bridges. It may be affirmed, as a general rule, that sound men are not permanently injured by it. In ordinary mines the chief

sensible effect of the barometric pressure is the variation it may cause in the natural ventilating current. Where the ventilation is wholly or partly artificial, these changes may be controlled. The introduction of compressed and cool air by machinery tends powerfully to reduce to a minimum the humidity of hot mines, and thus (as in the Comstock) to give an atmosphere in which free perspiration, rapidly evaporating, cools and refreshes the body. A comparison of the statements above made, as to the Comstock miners and the miners in the hottest mine of Cornwall, shows how much more can be endured and accomplished by workmen when thus protected from vitiated or over-humid air.

The injurious effect of working under artificial light, instead of sunlight, has been often asserted; but there is no definite proof of it. Where other conditions are wholesome, and the habits of the workmen are regular, this is not likely to have a traceable effect. At all events, it is subordinate to many other causes.

General Conclusions.—The British Commission, to which reference has been made, summed up its voluminous report in a few conclusions and recommendations, the substance of which I quote below, in order to point out how far they are applicable to miners in the United States.

The Commission finds that a large proportion of the diseases affecting miners in the metal-mines is to be ascribed to defective ventilation only. However various the opinions of physicians concerning the causes of the disease so well known under the name of miners' consumption or miners' asthma, there is in one respect a remarkable unanimity among all the experts, namely, that the health of the miner is chiefly affected by the quality of the air in which he works. This conclusion is emphasized by the results of very wide inquiry on the part of the Commission.

In the coal-mines, where special attention is paid to ventilation, on account of explosive gases, the mortality of miners, apart from accidents, is lower than in the metal-mines. Starting from this significant fact, the Commission recommends that some of the methods of artificial ventilation employed in the former should be more generally introduced into the latter, and favors particularly the use of furnaces in "upcast" shafts, to accelerate the natural current by heating the upward-moving column of vitiated air, and to prevent the stagnation or reversal of the current by change of season or weather.

With reference to other causes of disease, the Commission recom-

mends that every mine be provided with a conveniently situated, separate house, in which the workmen may change and dry their clothes; that boys under fourteen be not permitted to work underground; and that mechanical means be adopted for transporting the miners into and out of the mines. The man-engine is praised; but the system of hoisting the men in skips and cages is also pronounced satisfactory, provided the machinery be properly constructed and carefully tended.

These recommendations are as timely now as they were ten years ago, except that the increasing use of compressed air in mining has furnished an aid to ventilation not then considered. There is no proof that the metal-miners of America are less healthy than other laborers, and there is no need that they should ever become so. In my judgment a wise regard for financial economy alone will cause capitalists to do all that philanthropic considerations would require in dealing with the problem of hygiene in mines—a problem which contains, as the foregoing discussion shows, no fatally insuperable difficulties, and no insoluble mysteries.